GIS-based Construction Quality Management

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Speaker Background

Danny Kahler, PE, PTOE

25 Years in Civil Engineering
Licensed in Texas, Arkansas, Florida, and Utah

Independent Design Quality Assurance for State Highway 130
$1.3B Design-Build Tollroad, Austin, TX

Risk Engineering Program for the Intercounty Connector
$2.4B Design-Build Tollroad, Rockville, MD

Quality Management Program for the KCICON
$250M Design-Build Signature Bridge, Kansas City, MO

ASQ Vice-Chair for Design Firms and for the Development of a Body of Knowledge in Design Quality Management

Session Goals

- Understand the general ***characteristics*** of the information associated with construction quality
- Understand the ***differences*** between mapping coordinate systems and engineering coordinate systems
- Understand how the ***fundamentals*** of GIS can help contractors and engineers improve the management of construction quality

Let's Clarify Definitions

Traditional Quality Definitions

Quality Assurance (QA). All those planned and systematic actions necessary to provide confidence that a product or service will satisfy given requirements for quality.

Quality Control (QC). All contractor/vendor operational techniques and activities that are performed or conducted to fulfill the contract requirements.

Emerging Quality Definitions

- **Prevention:** The implementation of process controls to ensure that work is done correctly the first time
- **Appraisal:** The evaluation of work after it has been produced to determine whether or not it conforms to requirements (plans and specifications)
- **Internal Failure:** The interception, through appraisal, of nonconforming work before it is delivered or incorporated into following work
- **External Failure:** The failure of work after it has been delivered or incorporated into following work

Types of Construction QA

Inspection

Sampling and Testing

Construction Services

Inspection

Determining if the attributes of ***workmanship*** conforms to the plans and specifications.

Sampling and Testing

Determining if ***materials*** characteristics conform to the specifications.

Construction Services

- ***interpreting*** plans, specifications, inspections, samples, and tests.

What Does The Contractor Do?

- Contractors are ***responsible*** for their own process control (Prevention)
- Contractors may ***perform*** their own internal quality assurance (Appraisal) to make sure that their work meets plans and specifications
- With some exceptions (FHWA 23 CFR 637) contractor quality data is ***not legal*** for acceptance, i.e., the inspections, samples, and tests must be done under the direct supervision of a licensed professional engineer

What Does The Engineer Do?

- Engineers professionally ***assure*** whether or not the work is in general conformance with the plans and specifications.

- Inspectors and technicians may ***perform*** this work under the direct supervision of an engineer

- Evaluation, acceptance, rejection of the work is ***regulated*** as part of the practice of engineering

Regulation of Construction QA

California 2010 Professional Engineers Act

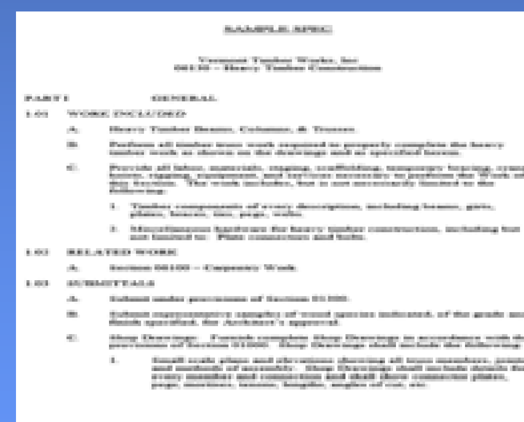
6703.1. Supervision of construction defined

"Supervision of the construction of engineering structures" means the periodic observation of materials and completed work to determine ***general compliance with plans, specifications, and design and planning concepts***. However, "supervision of construction of engineering structures" does not include responsibility for the superintendence of construction processes, site conditions, operations, equipment, personnel, or the maintenance of a safe place to work or any safety in, on, or about the site. For purposes of this subdivision, "periodic observation" means visits by an engineer, or his or her agent, to the site of a work of improvement.

Quality Assurance Information

- Conformance to ***Plans***
  - Horizontal Location
  - Elevation
  - Dimensions
  - Slopes
  - Size

- Conformance to ***Specifications***
  - Compressive and Tensile Strength
  - Durability and Toughness
  - Color and Texture
  - Tolerances
  - Other measurable physical properties



What's In Common?

- Everything has a ***GROUND LOCATION***.
- This makes project quality assurance ***different*** than manufacturing quality assurance.
- ***GROUND LOCATION*** can bring together what might normally seem to be disconnected quality assurance data.

Methods of Project Location

- Linear Projects
  – Station and Offset: ***Curvilinear*** alignments which are tied to XY coordinates. Complex projects may have dozens of separate alignments
- Area Projects
  – Local XY: ***Cartesian*** (rectangular) systems based on a local starting point.

GIS Project Location

- XY, or Northing and Easting
- Z, or Elevation
- Correct projection file
- Need to have correct units
  - US Survey Foot vs. International Foot?

Mapping vs. Engineering

- Mapping is usually tied to *earth location*. May have large scale distortions. Lat-Long and UTM most common.

- Engineering is just enough coordinate system to get the project ***built***. Some dimensions are relative to other elements. Absolute coordinates are often derived from State Plane Coordinates.

Advantage of GIS

- Can bring multiple coordinate systems into one view.
- Some quality data could be collected on paper using recreational GPS units.
- Can overlay project onto the “gold mine” of publicly available GIS data.

Various Engineering Coordinates

- State Plane at grid (Oklahoma DOT)
- State Plane with county scale factor (Texas DOT)
- State Plane with project scale factor (Missouri DOT)
- State Plane with scale factor and truncated (Utah DOT)
- Local XY based on iron pins (Many municipalities)
- Nearest tree or fence post (Many utilities)

Quality Assurance Data

- Inspections
  - Point: foundations, poles, connections, check dams, headwalls
  - Line: pipe, curb & gutter, guardrail, striping, conduits, concrete barrier, silt fence
  - Area: earthwork, subgrade, base, pavement, bridge deck, surface treatment, vegetation

Quality Assurance Data

- Samples and Tests
  - – Point: Density, Gradation,
  - – Lines: Lots (averaged samples or tests)
  - – Area: Lots (averaged samples or tests)
  - – Volume: Based on linear or area

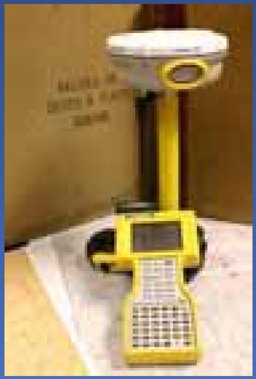
Quality Assurance Data

- Quantities
  - Point: Inlets, Poles, Manholes
  - Line: Curb, Pipe, Guardrail, Pipe, Conduit
  - Area: Subgrade, Paving, Bridge Deck
  - Volume: Based on linear and area

Other Data

- Pay Items – quantities tied to unit cost used to pay a contractor on ***design-bid-build***
- Cost-Loaded Schedule Activities – used to pay a contractor on ***design-build***
- Work Breakdown Structure – used to ***organize*** the work
- Materials Codes – used to ***classify*** materials
- Resources – manpower and equipment ***mobilized*** to the project

Recommended Accuracies



Layout: 0.01 foot (+/- 0.10 foot construction tolerances).

Survey Grade GPS or Total Station

Quantities: 0.1 foot to Subfoot

Mapping Grade Carrier – Post Processed

Density tests: Subfoot

Mapping Grade Carrier – Post Processed or RT Service

Gradation tests: 1 – 3 Feet

Mapping Grade Code – Real Time SBAS

Concrete tests: 2 – 10 Feet

Mapping Grade Code – Real Time SBAS

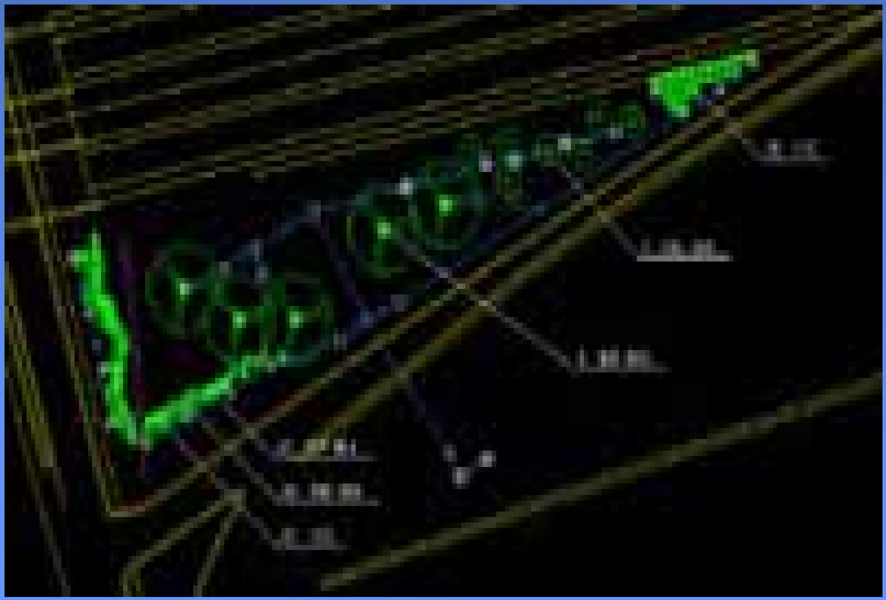
Project Resources and Environmental: 5 – 20 Feet.

Recreational Grade Code – Real Time SBAS

Master Design Files

Master Design Files are 2D CADD files of the raw design in the project coordinate system. Design elements in design files are drawn exact, with no text or dimensioning.

Design elements may be separated by levels or layers, or assigned to categories through an associated database



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Design Files as Background

- Can be used as a background on data collectors.
- Can be organized to only show key design elements.
- Gives the construction inspector the same view of the design as the design engineer.
- Can be used to verify correct layout using survey-grade positioning technology
- Geospatial PDF plans are an emerging technology

GIS for Quality Analysis

- Fit – are the project elements in the correct plan location, within the specification tolerances?
- Strength – do the materials in the project have the required strength? i.e. compressive, tensile, shear, abrasion, durability, etc.?
- Appearance – do the project elements have the required appearance?

GIS Advantages

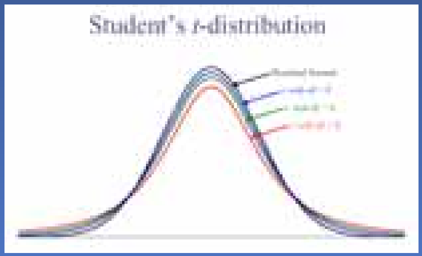
- See all quality:
  - In one view
  - Relative to time
  - Against compliance with plans and specs
  - Categorized by producer
  - Categorized by inspector
  - Categorized by risk

Possibilities

- “Show the location of all earthwork density tests”
- “Show all nonconformances on pavement alignment”
- “Show any gaps in inspection compared to the master design files”
- “Show all collected quantities compared against the monthly progress estimate”

Statistical Validation

- Allowed by FHWA under 23 CFR 637
- Most engineers are not trained in it
- Traditional data is difficult to collect



- GIS for both Quality Control and Quality Assurance makes data collection easier.
- Expand validation beyond just sampling and testing: Automated Machine Guidance, Smart Compaction, Electronic As-Builts.

Construction Quality Assurance

Traditional Way	*GIS Way*
Text-based	*Graphics-based*
Data in Office	*Data in Field*
Manual Forms	*Handheld Collector*
Separate Measurements	*Integrated Measurements*
Delay	*Immediate*
Custom	*Off the shelf*
One copy	*Infinite copies*

"I Need A Laptop"

- For ***years*** field inspectors have lobbied for laptops.
- Laptops are a ***coveted*** status symbol item for inspectors.
- Construction quality assurance won't ***improve*** unless we revolutionize the data collection process.
- Inspectors need ***reliable*** tools.
- Inspectors need to measure, collect data, and find information

Needs from Vendors?

- Software that directly imports master design files (.dgn. .dwg, or .dxf)
- Software that can use alignments (.gpk or .alg)
- Software that can use other databases for lookups (no hard-coded data dictionaries)
- *Can we lock ESRI, Bentley, Autodesk, Trimble, Topcon, Magellan, and Adobe all in the same room and not let them out until come up with a solution?*

Needs from Professionals?

- Control the quality of the design model
- Clearly define the project coordinate system
- Break the addiction to paper
- Understand relational data
- Train the “paraprofessional” (new ASCE term)
- Learn how to analyze data
- Can we start designing everything at GRID? Please?

Thank You For Attending

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